2.4.8.2 Verification of Receiver Performance (§2.2.8.2)

No specific test procedure is required to validate §2.2.8.2.

2.4.8.2.1 Verification of Receiver Sensitivity (§2.2.8.2.1)

No specific test procedure is required to validate §2.2.8.2.1.

2.4.8.2.1.1 Verification of Long ADS-B Message ~~is~~ As Desired Signal (§2.2.8.2.1.1)

Purpose/Introduction:

A desired signal level of –93 dBm applied at the antenna end of the feedline **shall** produce a rate of Successful Message Reception of 90% or better under the following ~~simultaneous~~ conditions:

a. ~~The~~ When the desired signal is ~~subject to~~ of nominal modulation (i.e., FM deviation is 625 kHz) and at the maximum ~~permitted~~ signal frequency offset ~~plus~~s, and subject to air-to-air Doppler shift at 1200 knots closure/opening.

b. ~~The~~ When the desired signal is ~~subject to the~~of maximum modulation distortion allowed in §2.2.2.4, at the nominal transmission frequency +/- 1 PPM, and subject to air-to-air Dopper shift at 1200 knots closure/opening..

Note: *The receiver criteria for Successful Message Reception of UAT ADS-B Messages are provided in §2.2.8.3.1. ~~This also ensures that the Basic ADS-B Message will be received at the same desired signal level.~~*

This test verifies the compliance of the UAT receiver with the sensitivity requirements when the desired signal is a Long ADS-B Message, under conditions of maximum frequency offset, Doppler shift, and ~~maximum allowed~~ modulation distortion.

Equipment Required:

Desired Message Signal:

Provide a method of supplying the UUT with ADS-B Messages having:

- RF Power Level: -93 dBm
- Center Frequency: 978 MHz +/- 2.0 kHz +/- 19.560 kHz (see Note below)
- FM Deviation: 560 kHz (measured at the minimum eye pattern opening per §2.2.2.4)
- Message Contents: Long ADS-B Message with pseudo-random payload data, and valid FEC Parity field per §2.2.3.1.3.
- Message Rate: 100 per second

Note: *Maximum Doppler shift at 1200 knot closing rate is derived as follows: Velocity (m/s) = 1200 NM/hr * 1853 m/NM / 3600 sec/hr = 617 m/sec. Doppler shift = 617 m/sec / 3e+08 m/sec = 2.06 PPM. Frequency deviation due to Doppler shift is 978 MHz * 2.06 PPM = +/- 2.01 kHz.*

Measurement Procedures:

The signal power level specified in this procedure is relative to the message source end of the transmission line used to interface the UUT receiver port to the message source.

The specified RF power level applied to the UUT shall be compensated for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures shall be lowered by 3 dB.

Step 1: Apply ADS-B Input Messages at maximum negative frequency offset

Apply the **Desired Message Signal** with the Center Frequency set to the minimum value (978 MHz – 2.0 kHz – 19.56 kHz) at the UUT receiver port.

Step 2: Measure the UUT receiver sensitivity

Decrease the input power level and determine the minimum RF signal required to produce an average reception rate of 90 percent by the UUT receiver.

Verify that this RF signal level is in compliance with the limits specified in §2.2.8.2.1.1.

Step 3: Apply ADS-B Input Messages at maximum positive frequency offset

Apply the **Desired Message Signal** with the Center Frequency set to the minimum value (978 MHz + 2.0 kHz + 19.56 kHz) at the UUT receiver port.

Step 4: Repeat UUT receiver sensitivity measurement

Repeat Step 2 to measure the UUT receiver sensitivity at the maximum positive frequency offset.

Step 5: Repeat for all Applicable Receiver Input Ports

Repeat Steps 1 through 4 for each applicable receiver RF input port of the UUT.

2.4.8.2.1.2 Verification of Basic ADS-B Message As Desired Signal (§2.2.8.2.1.2)

Purpose/Introduction:

A desired signal level of –94 dBm applied at the antenna end of the feedline **shall** produce a rate of Successful Message Reception of 90% or better under the following conditions:

a. When the desired signal is of nominal modulation (i.e., FM deviation is 625 kHz) and at the maximum signal frequency offset, and subject to air-to-air Doppler shift at 1200 knots closure/opening.

b. When the desired signal is of maximum modulation distortion allowed in §2.2.2.4, at the nominal transmission frequency +/- 1 PPM, and subject to air-to-air Doppler shift at 1200 knots closure/opening.

Note: *The receiver criteria for Successful Message Reception of UAT ADS-B Messages are provided in §2.2.8.3.1.*

Equipment Required:

Desired Message Signal:

Provide a method of supplying the UUT with ADS-B Messages having:

- RF Power Level: -94 dBm
- Center Frequency: 978 MHz +/- 2.0 kHz +/- 19.560 kHz (see Note below)
- FM Deviation: 560 kHz (measured at the minimum eye pattern opening per §2.2.2.4)
- Message Contents: Basic ADS-B Message with pseudo-random payload data, and valid FEC Parity field per §2.2.3.1.3.
- Message Rate: 100 per second

Note: *Maximum Doppler shift at 1200 knot closing rate is derived as follows: Velocity (m/s) = 1200 NM/hr * 1853 m/NM / 3600 sec/hr = 617 m/sec. Doppler shift = 617 m/sec / 3e+08 m/sec = 2.06 PPM. Frequency deviation due to Doppler shift is 978 MHz * 2.06 PPM = +/- 2.01 kHz.*

Measurement Procedures:

The signal power level specified in this procedure is relative to the message source end of the transmission line used to interface the UUT receiver port to the message source. The specified RF power level applied to the UUT shall be compensated for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures shall be lowered by 3 dB.

Step 1: Apply ADS-B Input Messages at maximum negative frequency offset

Apply the **Desired Message Signal** with the Center Frequency set to the minimum value (978 MHz – 2.0 kHz – 19.56 kHz) at the UUT receiver port.

Step 2: Measure the UUT receiver sensitivity

Decrease the input power level and determine the minimum RF signal required to produce an average reception rate of 90 percent by the UUT receiver.

Verify that this RF signal level is in compliance with the limits specified in §2.2.8.2.1.1.

Step 3: Apply ADS-B Input Messages at maximum positive frequency offset

Apply the **Desired Message Signal** with the Center Frequency set to the minimum value (978 MHz + 2.0 kHz + 19.56 kHz) at the UUT receiver port.

Step 4: Repeat UUT receiver sensitivity measurement

Repeat Step 2 to measure the UUT receiver sensitivity at the maximum positive frequency offset.

Step 5: Repeat for all Applicable Receiver Input Ports

Repeat Steps 1 through 4 for each applicable receiver RF input port of the UUT.

~~2.4.8.2.1.2~~2.4.8.2.1.3 Verification of Ground Uplink Message ~~is~~ As Desired Signal (§2.2.8.2.1.3)

Purpose/Introduction:

A desired signal level of –91 dBm applied at the antenna end of the feedline **shall** produce a rate of Successful Message Reception of 90% or better under the following ~~simultaneous~~ conditions:

a. ~~The~~ When the desired signal is ~~subject to~~of nominal modulation (i.e., FM deviation of 625 kHz) and at the maximum ~~permitted~~ signal frequency offset ~~plus~~s, and subject to ground-to-air Doppler shift at ~~600~~ 850 knots closure/opening.

Note: *The 850 knot ground station closure rate is derived from a 600 knot true air speed, added to a 250 knot worst-case wind velocity. The 1200 knot air-to-air closure remains valid because both aircraft are assumed to be within the same air mass, so the wind velocity makes no difference to the closure rate.*

b. ~~The~~ When the desired signal is ~~subject to the~~ of maximum modulation distortion allowed in §2.2.2.4, at the nominal transmission frequenct +/- 1 PPM, and subject to ground-to-air Doppler shift at 850 knots closure/opening.

Note: *This requirement assumes that the baud rate accuracy of the ground transmitter is 2 PPM. ~~This requirement ensures the baud rate accuracy supporting demodulation in the UAT equipment is adequate to properly receive the longer Ground Uplink Message (assuming that the baud rate accuracy of the ground transmitter is 2 PPM).~~*

This test verifies the compliance of the UAT receiver with the sensitivity requirements when the desired signal is a Ground Uplink Message, under conditions of maximum frequency offset, Doppler shift, and ~~maximum allowed~~ modulation distortion.

Equipment Required:

Desired Message Signal:

Provide a method of supplying the UUT with ADS-B Messages having:

- RF Power Level: -91 dBm
- Center Frequency: 978 MHz +/- 1.0 kHz (see Note below)
- FM Deviation: 560 kHz (measured at the minimum eye pattern opening per §2.2.2.4)
- Message Contents: Ground Uplink Message with pseudo-random payload data, with valid FEC Parity field and Interleaving per §2.2.3.2.
- Message Rate: 10 per second in the Uplink segment only.

Note: *Maximum Doppler shift at 850 knot ground speed is derived as follows: Velocity (m/s) = 850 NM/hr * 1853 m/NM / 3600 sec/hr = 438 m/sec. Doppler shift = 438 m/sec / 3e+08 m/sec = 1.46 PPM. Frequency deviation due to Doppler shift is 978 MHz * 1.46 PPM = +/- 1.5 kHz. ~~Maximum Doppler shift at 600 knot ground speed is derived as follows: Velocity (m/s) = 600 NM/hr * 1853 m/NM / 3600 sec/hr = 308 m/sec. Doppler shift = 308 m/sec / 3e+08 m/sec = 1.007 PPM. Frequency deviation due to Doppler shift is 978 MHz * 1.03 PPM = +/- 1.0 kHz.~~*

Measurement Procedures:

The signal power level specified in this procedure is relative to the message source end of the transmission line used to interface the UUT receiver port to the message source. The specified RF power level applied to the UUT shall be compensated for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures shall be lowered by 3 dB.

Step 1: Apply Ground Uplink Input Messages at maximum negative frequency offset

Apply the **Desired Message Signal** with the Center Frequency set to the minimum value (978 MHz – 1.~~0~~ 5 kHz) at the UUT receiver port.

Step 2: Measure the UUT receiver sensitivity

Decrease the input power level and determine the minimum RF signal required to produce a reception rate of 90 percent by the UUT receiver, averaged over a minimum of 100 received messages.

Verify that this RF signal level is in compliance with the limits specified in §2.2.8.2.1.2.

Step 3: Apply Ground Uplink Input Messages at maximum positive frequency offset

Apply the **Desired Message Signal** with the Center Frequency set to the maximum value (978 MHz + 1.~~0~~ 5 kHz) at the UUT receiver port.

Step 4: Repeat UUT receiver sensitivity measurement

Repeat Step 2 to measure the UUT receiver sensitivity at the maximum positive frequency offset.

Step 5: Repeat for all Applicable Receiver Input Ports

Repeat Steps 1 through 4 for each applicable receiver RF input port of the UUT.

2.4.8.2.2 Verification of Receiver Desired Signal Dynamic Range (§2.2.8.2.2)

Purpose/Introduction:

The receiver **shall** achieve a Successful Message Reception rate for Long ADS-B Messages of 99% or better when the desired signal level is between –90 dBm and –10 dBm at the antenna in the absence of any interfering signals.

Notes:

1. *The value of –10 dBm represents 120-foot separation from an A3 transmitter at maximum allowed power.*

2. *Certain installations that rely on over-air reception of the ownship transmission to meet the requirements of* §2.2.6.3 *may need to achieve Successful Message Reception at significantly higher levels than –10 dBm.*

This test verifies the compliance of the UAT receiver with the dynamic range requirements. The desired signal is the Long ADS-B Message.

Equipment Required:

Desired Message Signal:

Provide a method of supplying the UUT with ADS-B Messages having:

- RF Power Level: -90 dBm
- Frequency: 978.0 MHz
- FM Deviation: 625 kHz (measured at the minimum eye pattern opening per §2.2.2.4)
- Message Contents: Long ADS-B Message with pseudo-random payload data, and valid FEC Parity field per §2.2.3.1.3.
- Message Rate: 100 per second (recommended minimum)

Measurement Procedures:

The signal power level specified in this procedure is relative to the message source end of the transmission line used to interface the UUT receiver port to the message source. The specified RF power level applied to the UUT shall be compensated for the maximum line loss for which the UUT receiver has been designed. For example, if the line loss is 3 dB, then each of the RF message power levels specified in the test procedures shall be lowered by 3 dB.

Step 1: Apply ADS-B Input Messages

Apply the **Desired Message Signal** at the UUT receiver input port.

Step 2: Measure the UUT receiver sensitivity

Decrease the input power level and determine the minimum RF signal required to produce an average reception rate of 99 percent by the UUT receiver. At least 1000 message receptions should be measured in making this determination.

Verify that this RF signal level is in compliance with the limits specified in §2.2.8.2.2.

Step 3: Verify the UUT receiver dynamic range

Starting from the signal level measured in Step 2, increase the input signal by 10 dB steps, up to a level of –10 dBm.

At each step, verify that the receiver properly detects and decodes at least 99% of the Desired Messages received per §2.2.8.2.2.

Step 4: Repeat for all Applicable Receiver Input Ports

Repeat Steps 1 through 4 for each applicable receiver RF input port of the UUT.

2.4.8.2.3 Verification of Receiver Selectivity (§2.2.8.2.3)

Purpose/Introduction:

These test procedures verify that the receiver **shall** provide the following minimum signal rejection ratios as a function of frequency offset as listed in Table 2-65, for reception of Long ADS-B Messages at a 90% Successful Message Reception rate, applied at a level of –93 dBm or less. The interference source is an un-modified carrier applied at the frequency offset.

Equipment Required:

The tests performed in this subparagraph require the following equipment:

a. Vector Signal Analyzer (VSA), or an equivalent Signal Analyzer, with minimum capabilities of displaying the envelope of a captured ADS-B Long message, displaying the associated spectrum, band power markers, and the corresponding computed band power. Examples: Agilent HP89441A, or the Agilent HP89600 series.

b. Signal Generator (SG), with minimum capabilities of up to 1 GHz carrier, power levels up to 0 dBm, continuous wave (CW) and digital two-state FSK modulation at a rate greater than 1 megabits/second, selectable root raised cosine and rectangular filtering, internal and external triggering, programmable power levels and bit states. Example: Rohde & Schwarz (Tektronix) SMIQ-02B.

c. Four Terminal Hybrid Junction with a frequency range covering 1 GHz.

For this subparagraph, configure the Vector Signal Analyzer equipment for Vector Mode according to Table 2-99.

Note: *Equipment parameter labels, menus, setup options, and units may vary from one manufacturer to another, and parameter labels are usually abbreviated. In Table 2-99 and Table 2-100, text enclosed in brackets is not displayed on the HP89441A display. The bracketed text is added to clarify the functional terms and setting values for those using neither the HP89441A, nor the SMIQ-02B.*

Table 2-99: Vector Mode Configuration

VECTOR SIGNAL ANALYZER PARAMETER SETTINGS	
Parameter Item/Function	**Parameter Setting Value**
Preset	(press to Preset Equipment)
Instrument Mode	Vector
Frequency / center frequency	978 MHz
Frequency / frequency span	preferably 5 MHz
ResBW/Window / main length	450 us
ResBW/Window / main window	Hanning
ResBW/Window / num[ber of] freq[uency] p[oin]ts	3201
Range / ch[annel] 1 [signal] range	–35 dBm
Time / gate	off
Time / gate length	400 us
Time / ch[annel]1 gate d[e]l[a]y	25 us
Average / average	on
Average / num[ber of] averages	50
Average / average type	rms expo[nential]
Trigger / trigger type	IF ch[annel]1
Trigger / ext[ernal] level	0.0005 V[olts]
Trigger / ch1 delay	-17.5 us
Display	2 grids
Trace A – Measurement Data	main time
Trace A – Data Format	magnitude linear
Trace A – RefLvl/Scale / Y ref level	0 uVpk
Trace A – RefLvl/Scale / Y per div[ision]	700 uVpk
Trace A – RefLvl/Scale / ref[erence] position	0 %
Trace B – Measurement Data	spectrum
Trace B – Data Format	magnitude log(dB)
Trace B – RefLvl/Scale / Y ref level	-70 dBm
Trace B – RefLvl/Scale / Y per div[ision]	7.5 dB
Trace B – RefLvl/Scale / ref[erence] position	100 %
Trace B – Marker Function / band power markers / band pwr mkr	on
Trace B – Marker Function / band power markers / band center	978 MHz
Trace B – Marker Function / band power markers / band width	2.5 MHz
Trace B – Marker Function / band power markers / [computation]	band power

For this subparagraph, configure the Signal Generator equipment according to Table 2-100.

Table 2-100: Signal Generator Configuration

SIGNAL GENERATOR PARAMETER SETTINGS	
Parameter Item/Function	**Parameter Setting Value**
Preset	(press to Preset Equipment)
RF ON/OFF	RF OFF
FREQUENCY	979 MHz
LEVEL	-35 dBm
DIGITAL MOD[ULATION] / STATE	OFF

Measurement Procedures:

Step 1: Equipment Setup (§2.2.8.2.3)

For the tests in this subparagraph, configure the Vector Signal Analyzer according to the Vector Mode setup listed in Table 2-99. See Appendix N for the state file "UAT-VECT.STA" to automatically setup the HP89441A Vector Signal Analyzer. As the very last configuration step, set Time / gate to "on."

Configure the Signal Generator equipment according to the setup listed in Table 2-100.

Step 2: Receiver Selectivity Pre-Test Setup (§2.2.8.2.3)

Using a Four Terminal Hybrid Junction, connect the Signal Generator, and an attenuated ADS-B Transmitter, to the ADS-B Receiving Equipment, and to the Vector Signal Analyzer. At the output of the ADS-B Transmitter, adjust the attenuation to present a signal of –50 ± 0.5 dBm to the ADS-B Receiving Equipment, and initiate a series of Long ADS-B test messages, each having the following message elements: the 36 bit SYNCH, followed by a 272 bit Payload having a pseudo-random series of bits which changes for each successive message, and a 112 bit FEC as generated by the Reed-Solomon algorithm. Trace A should show: 1) a stable triggered message envelope, 2) that the leftmost vertical gating line occurs just after the rise of the envelope, and 3) that the rightmost gating line occurs just before the fall of the envelope (reduce "Time/gate length" by 5 microseconds, if necessary, to satisfy this setup).

Step 3: Receiver Selectivity Pre-Test Setup (§2.2.8.2.3)

The Vector Signal Analyzer Trace A display should resemble the upper trace of Figure 2-13, and the Vector Signal Analyzer Trace B display should resemble the lower trace of Figure 2-13. Verify that the ADS-B Receiving Equipment is reporting all received test messages.

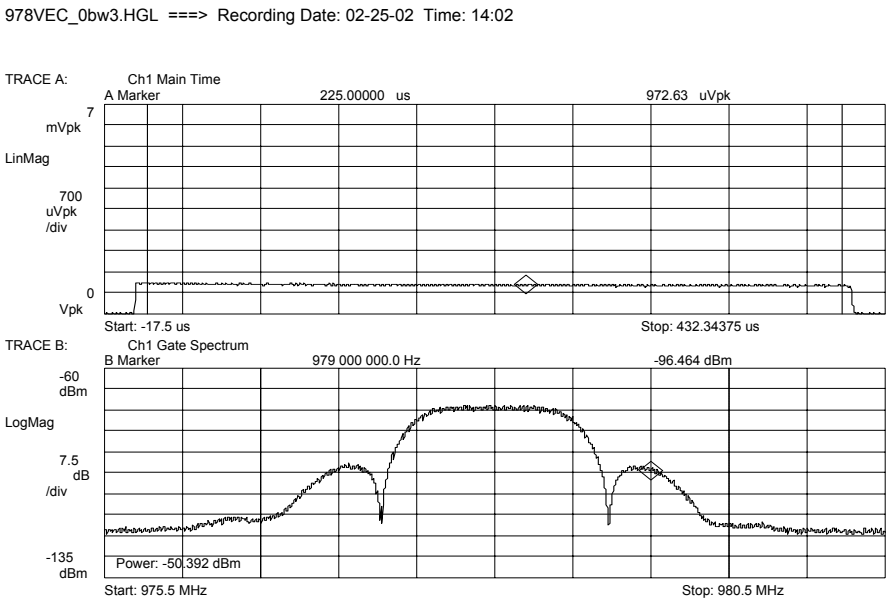

Figure 2-13: ADS-B Long Message Envelope & Spectrum – No Interference

Step 4: Receiver Selectivity Pre-Test Setup (§2.2.8.2.3)

Ensure that the Signal Generator is programmed for Continuous Wave at a frequency of 979 MHz, and ensure that the Vector Signal Analyzer Range / ch[annel] 1 [signal] range is –35 dBm. Turn the Signal Generator RF ON/OFF to "ON," place the Trace B marker at 979 MHz, temporarily turn the Vector

Signal Analyzer Average / average to "off," and adjust the received Signal Generator signal level P_{CW} ("Power" displayed at lower-left of Trace B) to be –35 ± 0.5 dBm. The Vector Signal Analyzer Trace A display should resemble the upper trace of Figure 2-14, and the Vector Signal Analyzer Trace B display should resemble the lower trace of Figure 2-14. Verify that the ADS-B Receiving Equipment is reporting all received test messages.

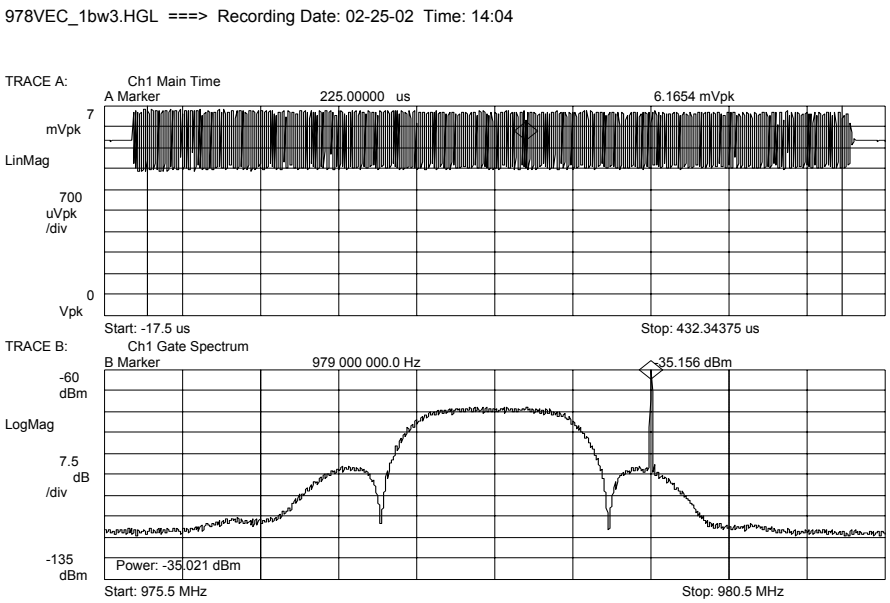

Figure 2-14: ADS-B Long Message Envelope & Spectrum– With CW

Step 5: Receiver Selectivity Test (§2.2.8.2.3)

Reduce the Signal Generator output by ~~40~~ 43 dB, and reduce the ADS-B Transmitter output by ~~40~~ 43 dB so that the UAT test message power level at the ADS-B Receiver input is P_{RCVR} = ~~–90 ± 0.5~~ -93 dBm. Using Table 2-101, for each class of equipment, and for each frequency offset (above and below center frequency), adjust the Signal Generator Continuous Wave level at the ADS-B Receiver input to the level shown (adjusting the Vector Signal Analyzer Trace B - Marker Function / band center frequency as needed), and adjust the Vector Signal Analyzer Range per column 4 of the Table (or as needed to avoid distorted results). In each case, count a total of at least 2500 test messages, count the number of good messages, and verify that the ADS-B Receiver is reporting good received test messages at a minimum of ~~99~~90% Message Success Rate.

Table 2-101: Selectivity Rejection Ratios

Center Frequency Offset, f_0	Continuous Wave Interference Level (dBm)		Vector Signal Analyzer Range
	Equipment Class A0, A1L, A1H, A2	Equipment Class A3	
-1.0 MHz	~~-80~~83	~~-60~~63	-50 dBm
+1.0 MHz	~~-72~~78	~~-50~~53	-45 dBm
±2.0 MHz	~~-40~~43	~~-40~~43	-35 dBm
±10.0 MHz	~~-30~~33	~~-30~~33	-25 dBm